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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

THE FLUORESCENT COLORS OF PLANTS[1]

THERE are many fluorescent substances in plants. It was in one of these, quinine, that Sir John Herschel (1845) recognized the peculiar property of emitting "superficial light" of a different character from that transmitted. Twelve years earlier, Sir David Brewster (1833) demolished the Newtonian view of the nature of leaf-green by studying its absorption spectrum. By this means he was led to find that, on observing the light transmitted through increasing densities of chlorophyll, the color of the beam changed from green through yellow and orange to red. "This mode of examining a spectrum by reflection from the particles of a fluid exhibits the phenomenon of opalescence in a very interesting form," he said, adding that he had observed this opalescence or imperfect transparency "almost always in vegetable solutions," and compared it to that in fluorspar, already well known to the mineralogists, and which prompted Sir George Stokes, nineteen years later, to propose, though reluctantly, as giving way to the blandishments of some evil spirit, the term fluorescence. Of the fluorescence of this mineral he remarked, "the brilliant blue of the intromitted pencil is singularly beautiful," and when we look at this specimen before us we can hardly blame him for his rhapsody, nor for his failure to interpret to the satisfaction of later physicists the phenomenon which so intrigued his thought. To grasp clearly the nature of fluorescence was the work of Sir George Stokes, who, my friend and colleague Professor A. S. Eve tells me, was given to working in the "back scullery and a small one at that," using the leaves of laurel and other plants which grew in his garden; and thus was led to the establishment "of a great principle with accommodation and apparatus which would fill the modern scientific man with dismay." This principle is now the food of scientific babes and sucklings, into which happy company we are each of us introduced when we venture into a new field. If their cries are not always intelligible, they at least know what they are after. It will be agreeable, I believe, to recall the experiment which Stokes did, and which gave him the clue to the mystery of fluorescence. It was this. He put some chlorophyll solution into a test tube, and

[1] Address of the vice-president and chairman of Section G—Botany—American Association for the Advancement of Science, Cincinnati, Ohio, December, 1923.

moved it across a spectrum beginning at the red end. "When plunged into the invisible rays, it was certainly a curious sight to see the tube instantly lighted up:[2] it was literally darkness visible. Altogether the phenomenon has something of an unearthly appearance." I have quoted these passages from the writings of Brewster and of Stokes, because their words appear to me to show with what fulness of joy they worked. They seem to have felt that life is more than meat, and the body than raiment.

In order to determine the origin of this curious light, Stokes used a simple but ingenious method of analyzing prismatically the spectrum when reflected by chlorophyll, and by the green leaf, thus obtaining what he called a "derived spectrum."[3]

He found in this way that the fluorescent light is derived by increase of wave length from all the light of wave length shorter than that of the fluorescent light in various amounts. When stated meticulously, this is the Stokes rule. It is with this kind of light that we are now concerned.

Stokes thus settled once for all the fact that chlorophyll in the living leaf is fluorescent. Since then various methods have been used to study the phenomenon in living plants. Simmler (1862), whose curiosity had been prompted by the uncanny illumination which prevails during total solar eclipse, thought to explain the red appearance of foliage when viewed through a filter devised by him as due to the fluorescence of the chlorophyll. Lommel (1871), however, criticized his method, pointing out that the red transmitted by his filters was the portion of the spectrum beyond the fluorescence band of chlorophyll, and devised a filter which would permit only the light lying in this region. With this filter foliage appears black, and so he called his filter, when made up like a pair of dromoscopes (automobile goggles), a melanoscope, in contradistinction to the erythrophytoscope of Simmler.[4]

Another method was that of Hagenbach (1874), quite recently used in modified form by K. Stern in his study of fluorescence in *Chlorella*. This consists in projecting upon the material a concentrated beam of light which has been purged of the light from red to yellow-green by a filter, and observing the fluorescent light with any desired means. The spectroscope enables one to analyze it with exactitude. These and similar methods have to do with material in the bulk, while one of the great desiderata of the biologist is to get at appearances in the small. Accordingly, we may now briefly trace the direction of effort to accomplish this.

We owe to the development of general interest in colloidal phenomena the development of the optical means to this end, although such means had originally been achieved in principle much earlier (Siedentopf, 1907). I refer to the arrangement for ultramicroscopy devised by Siedentopf and Szigmondy (1903) foreshadowed by the luminoscope of Tswett (1901) in the matter of orthogonal illumination. This consisted in a light-tight box arranged to permit a beam of strong light to traverse a tube of fluid longitudinally. The contents of the tube were observed laterally. The ultramicroscope was an arrangement for achieving the same purpose with the added high magnification, since a water-immersion lens was used for the lateral observation. In this way suspended particles could be revealed. We well know the purpose this instrument has served in the study of suspensions: Raehlmann (1906) and Gaidukow (1910) used it for the examination of chlorophyll, the latter author, in conjunction with the dark-field condenser, also for studying a variety of plant objects. It yields little to the biologist, however, for it is adapted pri-

[2] I have made a transposition of the original text.

[3] The derived spectrum may be seen microscopically by the following means. An Abbe condenser is stopped so as to allow only a marginal cylinder of light to pass through. The parallel beam of a strong illuminant is then directed toward the margin of the mirror so that extreme oblique illumination is achieved. The iris diaphragm is then closed enough to make a slit between its margin and that of the central stop. A spectrum may then be seen in or nearly in the middle field. If a mat of blue green algae (best a red fluorescent species) is then adjusted so that the spectrum falls upon it, the blue-violet-ultraviolet portion is seen to be the seat of red light also.

[4] The point at issue between these authors has lately been of interest in connection with the use of light filters for the detection of camouflage. "Property" forests and coppices when observed through a suitable filter appear red, while green paint, used in imitation of them, appears black. This was achieved independently by Mr. C. F. Stiles, who has afforded me a sample of his filter. This transmits the red beyond $\lambda = 660$. I have found a combination of ruby and violet glass which acts as this, transmitting from 650 on. Simmler's filter (cobalt and iron oxide glasses combined) transmitted the red beyond the B line (foliage appearing red), while Lommel's transmitted the red between B and C (foliage appearing black). I have been able to duplicate Simmler's result but not yet that of Lommel. Lommel's result seems to be due to the reduction in the amount of red light to a narrow band. When I illuminated a Ficus leaf with light devoid of red- yellow- yellow-green, while I could observe a fluorescence red band spectroscopically, the leaf did not appear red to the eye through the Stokes filter, though with stronger light than that used (400 W lamp) it might have. It seems entirely probable that Lommel's contention is correct, namely, that the red appearance of foliage as seen through appropriate filters is due largely to reflected red, but it is also probably reinforced by fluorescent red.

marily to the examination of fluids and gases. The needs of the biologist soon led to the construction of the dark field illuminators or mirror-condensers, the prototypes of which were those made in England in the early fifties by Th. Ross, by Wenham and by Stevenson.[5] It is to be noted that they at first made use of the reflected light cone or cone of illumination, a method which did not suit the optical means then available for the examination of very minute objects. Further, with homogeneous immersion the beam passed upward into the objective. In the dark field condensers later devised, namely, at the beginning of the present century, by German manufacturers, a hollow cone of brilliant light of wide angle was obtained, the apex of which, lying between the object slide and cover slip, served to bring the object into view by light which is reflected or refracted into the eye. Much study has been devoted to the optical complexities of the image received (*e.g.*, by Gaidukow). Even diffraction images have their use in interpretation of the object picture.

Among the many purposes to which the dark field condenser has been put is that of seeing and studying fluorescence, especially of chlorophyll. It is to this that our present interest attaches.

Raehlmann (1906) examined chlorophyll[6] and described the suspensoids therein as minutest blood-red particles, resolved by high magnification from a red light cone.[7] He made combinations of chlorophyll and other substances, especially proteins, and speculated on the variety of coloration as possibly due to combinations of this kind.[8]

Gaidukow's studies embraced a wide range of objects, by way of testing out the capacity of the new optical tools found in the various condensers then extant. Among them were a number of plants and chlorophyll. The latter, he found, gave, in alcoholic solution,[9] the red light cone, with no suspensoids, but which appeared on adding water. These he described as red and green, their relative numbers changing with added water till all became colorless. Concerning his observations on plant cells, we note only those observations which bear on the present theme. He examined a series of algae, but only in *Vaucheria* did he observe oil droplets which displayed fluorescent red, though he did not state it thus. For the rest he speaks of seeing white, blue, pale blue-green, red and sealing wax red points in a blue-green *Oscillatoria;* in a violet species, the blue-green points of light were replaced by violet. Somewhat similar results were obtained for *Porphyridium cruentum.* These observations as set down tell us nothing of fluorescence. Certainly Gaidukow did not see general fluorescence in the chromatophores.

At about this time Reichert devised the so-called fluorescence microscope—that is, an arrangement by which objects might be observed when submitted to ultraviolet rays. For this purpose a source rich in these rays, and a train of quartz lenses with appropriate filters were used. Tswett (1911) made the first record of observation of chloroplasts and of *Oscillatoria* which glowed carmine red, the latter inclosed in a pale blue wall. With a spectroscopic ocular he determined the fluorescence spectrum of *Spirogyra* and of *Oscillatoria* (lambda—685–670 and 660–650 for *Spirogyra* and lambda—670–630 for *Oscillatoria*), which would have been more extensive had the full spectrum been used.

Similar observations have been made by Gicklhorn (1914), confirmatory of Gaidukow's work.

The foregoing is approximately the net result up to 1921, when K. Stern published his work on the fluorescence of *Chlorella,* which, however, he studied by the modified Hagenbach method as above mentioned. He applied ultramicroscopy[10] only to solutions and suspensions of chlorophyll, and found himself unable to agree with Raehlmann as to the occurrence of red fluorescent particles. In this I find that I have to support Stern. The red color observed by Raehlmann may have been due to refraction effects, whereby the particles become apparent as red discs at a high focus. Larger suspensoids, or rather emulsoids, procured by preparing emulsions of water and lipoid, appear as minute fluorescent droplets, corresponding to Raehlmann's account. In order to put the matter to test, and having regard also to Stern's work, I prepared a suspension of chlorophyll[11] in alcohol-water, but in no case could I find

[5] For the history of the dark-field illuminator see Locy (1923), Beck (1923) and Siedentopf (1907).

[6] Merck's *chlorophylli puri solutio aquosa.*

[7] Of the Siedentopf and Szigmondy apparatus.

[8] Czapek (Biochemie der Pflanzen 1: 564) appears to have thought that Raehlmann claimed that he saw the fluorescence of chloroplasts ultramicroscopically, but I can not find evidence in the paper cited by Czapek that he made this claim.

[9] Herlitzka (1912) could see no particles proper to phaeophytin-acetone solutions.

[10] Using the Siedentopf and Szigmondy apparatus.

[11] Powder of Saponaria leaves dried 48 hours *in vacuo* at 60 degrees C. was extracted 6 hours with petrolic ether, dried and then extracted 6 hours with ethyl ether. Most of the lipoid had therefore been extracted, but a small amount remained, doubtless. After evaporation, the chlorophyll was taken up with ethyl alcohol, which was mixed with water to make 25, 50 and 75 per cent. mixtures. 25 per cent. water: suspensoids small, uniform, appearing white in apex of inverted light cone; 50 per cent: suspensoids somewhat larger white, fluorescent in ultraviolet; 75 per cent. water: flocculation, the small flocks green, suspensoids white, fluorescent in ultraviolet.

any evidence of red color proper to the suspensoids. Nevertheless, these suspensoids are fluorescent.

Stern was able to see that *Chlorella*, in bulk suspensions of pure culture, is fluorescent when illuminated by light passed through a filter admitting light between E and H only. By comparing the fluorescence of various chlorophyll mixtures, he found that only those into which lipoid has been introduced showed fluorescence. Without tracing his argument, he concluded that only molecularly dispersed chlorophyll is fluorescent, and that colloidal or solid chlorophyll is not. Since chlorophyll in the chloroplast (as in *Chlorella*) is fluorescent, it is therefore molecularly dispersed, though it may be in a viscous solvent (lipoid) itself colloidally dispersed.[12]

We have thus indicated the net result from the use of microscopic means, which as late as 1921 had yielded very little. Were it possible to see the fluorescence of chlorophyll and other pigments microscopically and at the same time the structures involved, it would give us an additional means of investigation. Such means we now have in the dark field illuminator of wide aperture, when used in the manner which I have already described (1923). The method consists in viewing the object at the apex of the light cone after it has been reflected from the cover-glass.[13] To this end are required a thin object slide and a dry objective supplied with an inside stop, the latter to obviate the flare, which is present, though to less extent than with an oil immersion.

By this means we obtain, in general, a softer illumination, albeit brilliant enough for very many purposes, and a completely black field. But when fluorescent organisms (especially those containing the water soluble pigments, phycocyanin and phycoerythrin, namely, the blue-green algae, some diatoms, florideae, etc.), are viewed, a most remarkably beautiful scene is produced, one which has "something of an unearthly appearance," to quote Stokes's words again. I show you a series of reproductions of organisms made by color-process photography[14] which, striking as I venture to believe they are, do the original subjects scant justice, as you will see on examining the preparations which are ready for your inspection.

It will have been observed that the dominating light received by the eye is that of fluorescence. This is more or less so according to the technique of preparation and of optical manipulation. Inevitably, when the entire spectrum is used, the total illumination consists of waves lengths of all dimensions, so that the spectrum obtained (with a spectroscopic ocular) would not be a pure fluorescence spectrum. In order to prove that the dominant color seen is that of fluorescence, I have photographed *Oscillatoria sancta* illuminated with light passed through a filter (methylene blue) which admitted light = λ 520 to 400 and 750 to 720 only. The image was passed through a yellow filter transmitting only waves lengths longer than 560, when it has much the same appearance to the eye as when seen in the fluorescence microscope. Having determined spectroscopically that the light thus to be received by the negative plate was embraced between 580 and 560 (approx.), this being the fluorescence spectrum of the organism as thus illuminated (and which corresponds fairly closely with the results of Tswett, 1911, and with the fluorescence spectrum of the extracted phycoerythrine [λ = 550 to 670] the plate was exposed for five hours, with the result which is shown you. The photograph of *Spirogyra* shown was made in similar fashion but with eleven and one half hours' exposure. You will observe that no trace of reflection from cell-walls or other bodies is visible, as is the case if the photograph is made with full illumination, though using only an ocular filter admitting only red. Here, as you see by the photograph, we get reflected red. In one negative bacteria may be seen thus illuminated, but there is little doubt that this color is reflected fluorescence red.

It should be noted that the colors achieved by color process photography do not correspond with more than loose approximation to the colors which emanate from the objects, and that one can just as easily prove that an object is green as that it is red, by the particular method which I have employed. You are, therefore, asked to add a measure of faith to sight in beholding these photographs. As a rock on which faith may rest, I show you the spectra in diagram, from which it will be seen that the fluorescence color of *Spirogyra* should be a deep red, while that of phycoerythrin should be a yellow-red or orange.

The advantage of this method of using the dark-field illuminator lies, however, not merely in rendering visible the fluorescence in the organism—this it does only with difficulty for chloroplasts, which demand a special technique, but in rendering visible structure at the same time. The former purpose is well served by the fluorescence microscope, which, however, does not lend itself to the study of structure. Objects thus seen have, moreover, low visibility. I have also had some opportunity of using the mercury-vapor lamp, the light being served to the object through a quartz dark field illuminator. This

[12] Space limits command us to refrain from entering upon the much discussed problem here indicated, that of the condition of chlorophyll in the living chloroplast.

[13] Thus returning to the earlier method of Ross and of Wenham.

[14] Including various species of *Chroococcus, Oscillatoria, Nostoc, Arthrospira* (3 spp.), *Cylindrospermum, Chantransia, Spirogyra, Pleurococcus,* etc. The Paget method was used.

has no advantage for achieving the results described over a 400 watt filament lamp or a 4 ampere arc, though with suitable filters it will be very useful for a spectrocopic study of living organisms.

It should further be remarked that the failure to observe fluorescence in organisms under the ordinary conditions of dark field illumination lies in part in the fluorescence-dispelling power of reflecting surfaces, and it is at the apex of the upright cone of light that this is at the maximum. For this reason, also, one employs mounting media which obviate these surfaces as far as possible. (Glycerine, cane-sugar solution, etc.) Nevertheless, even with homogeneous immersion lenses one can see fluorescence, particularly when one has learned its appearance. As has often been observed, solutions of fluorescent substances (chlorophyll, eosin, etc.) are readily seen to be fluorescent.

In the above regard, the chloroplast offers considerable difficulty, partly because of the very low visibility of the fluorescence (it being dark red) and partly because of granules, the nature of which we are in doubt. I illustrate these facts with a plate of chlorophyll in balsam and with one in collodion, with and without the addition of a small amount of oil. You will observe that the visibility of the fluorescence is at once dispelled when one backs these plates with one of ground glass. And when a black velvet disc with white spots is so placed, the fluorescence is dispelled by the white spots, which now appear green. It seems probable that the green granules which are to be seen in chloroplasts, the whole stroma of which appears fluorescent, are really colorless, appearing white, just as cyanophycin granules do.

We may now pass on to consider the results which have accrued from the use of the method, avoiding too much detail. Fluorescence has been observed in a number of bacteria (casual observations), in all the species (about 20) of the blue-green algae examined with one notable exception of an apparently undescribed species, in some desmids, in several species of *Spirogyra*, in *Hydrodictyon*, in several of the *Protococcales* (*Gloeocystis, Kirschneriella, Excentrosphaeria*), in *Gloeocystis*, in *Vaucheria*, in several diatoms (*Navicula, Meridion, Bacillaria*, etc.), and in the fresh-water floridean, *Chantransia violacea aff.* and finally in the chloroplasts of a number of higher forms.

A feature of the blue-greens which stands out is the variety of nuance. In general, the blue-green species which contain phycocyanin are fluorescent red, while the brownish or violet tinged kinds containing phycoerythrin are orange fluorescent. Boresch (1921) found an alignment of species, 22 in number, in accordance with this. But I have observed that in either group there are less striking but still obvious shades of color suggesting mixtures, from almost if not quite pure yellow to deep carmine red. One explanation obviously may be found in the admixture of light due to reflecting surfaces, a matter which has been discussed since 1883 (Reinke), and as I have experimentally illustrated. That this is the case in the blue-greens is shown by the fact that cells of some species of *Oscillatoria* which have been shrunken by cane sugar or glycerine appear deep red, but as the shrinkage disappears by taking up water, they become orange which appears deeper where there are few granules and light where there are many, as near the transverse walls. Another explanation may be found, possibly, in the modifying effect of one fluorescent substance on another, illustrated when I mix alcoholic solutions of fluoresceine and chlorophyll. I am not altogether convinced that the blue and red pigments do not both occur in the same species, some observations suggesting this. At all events, in nearly all cases we have to reckon with the presence of both chlorophyll and of one of the water-soluble pigments.

As to the way in which the pigments occur, I have already advanced evidence for believing that the phycocyanin (or phycoerythrine) is confined to numbers of minute vacuoles. It is very difficult and often impossible to resolve them except in very large cells, such as the spores of *Cylindrospermum*, in which they may be identified—their fluorescent contents also—with the oil immersion. They seem not to be confined to the so-called chromatophore, but there is a difficulty of observation of this relation as also of the limits of the vacuoles, arising from the masking of finer structure by the fluorescent pigment. This has suggested the importance of the use of ocular filters, as did Timiriazeff (1904) in observing chlorophyll bodies. Photographers have found out that this method enables them to get results otherwise impossible, and microscopists will profit by the same method.

In the blue-green algae[15] phycoerythrin does not seem to occur in this way, but rather as in the Florideae, in which it is confined within the chloroplasts. In these it is coterminous with the chlorophyll and with the limits of the chloroplast. Its water solubility suggests that the relation of the pigment to the plastid is an adsorption one. It is more difficult to decide about chlorophyll, even assuming that the above is true. Its lipoid solubility, and its index of fluorescence in various water-lipoid mixtures have led Stern to argue strongly for the view that it occurs in the chloroplast dissolved in lipoid, the lipoid itself, it may be, being dispersed.

[15] We are accustomed to this adjective, but it would be useful to use red-green to distinguish those species containing phycoerythrin.

The above statements are avowedly subject to revision; nevertheless, it may be confidently hoped that the method under discussion will prove of material assistance in the solution of this problem.

A further word on the differences of fluorescence color. I have repeatedly observed that two species almost identical, but, I suppose, not entirely so, differ in fluorescence colors, irrespective of the genus. In this connection I was interested to note that Teodoresco found in Bucharest *Nostoc commune* containing phycoerythrin, whereas other examples of this species contain phycocyanin (as does a sample I have from China). These may be examples of mutability of color as observed by Gaidukow (1902), but I incline to think not, and that these are different organisms.

The bizarre color effects observed by Gaidukow by means of the upright light cone I have also seen, but they may also be seen in nematodes which so frequently occur with blue-greens. One is tempted to revert to the theory of generation of a pre-Redian age and to believe that these pests are derived from filaments of *Oscillatoria,* or to attach little importance to mere color appearances, many of which are refraction effects. The extruded white cyanophycin granules which look very convincingly red at a high focus, appear blue *in situ* in red fluorescent species because seen through a screen of blue pigment as already pointed out. It is, as a matter of fact, very difficult to ascribe a particular color to minute granules when seen with dark field illumination, due account of which has been taken before voicing any of the preceding statements.

The heterocyst in no case observed contains any fluorescent pigment.

Of three species of *Arthrospira,* found in material sent to me by Professor Faull from Toronto, one is red-, one orange-fluorescent and one, greenish yellow by transmitted light, is beautifully opalescent blue when viewed with the dark field illuminator (photograph), but contains no fluorescent pigment, it being quite invisible in pure ultraviolet (fluorescence microscope). While slender, it is a striking species,[16] sharply contrasting with the fluorescent[17] species in the wide amplitude of the spirals. As you see in the photograph, cyanophycin granules appear white, as they do also in *Chroococcus* (slides).

When the blue-greens are heated enough to destroy the water soluble pigment, they become green. The chlorophyll now not being masked, the fluorescence spectrum may be seen with the microspectroscope, using the inverted light cone, and the appropriate filters. It lies between 650 and 700.

Aside from the blue granules (cyanophycin) of the deep-red fluorescent species, there are visible other granules. These are perhaps the gas vacuoles according to Klebahn (1922). They shine very brilliantly, as do also entire cells, which, however, appear to be dead. I have observed similar granules extruded from chloroplasts, while sometimes yellow granules have been seen (*Aspidistra*).

After lying in glycerine for some time, varying with the species, the water soluble pigment leaches out, and its fluorescence may then be seen in the apex of the light cone. In this way, with even a very small amount of material, the pigment may be identified, though there may be insufficient to give a color by transmitted light.

Diatomaceae: The difficulty of observation encountered by Gaidukow (1910), *viz.,* the masking of the interior coloration by the shell, is in many cases quite overcome by using the inverted light cone, though not always or not entirely. Furthermore, the chloroplasts themselves afford reflecting surfaces which have the same effect. Since Gaidukow failed to observe anything, either of structure or coloration, the following observations indicate a distinct advance.

The diatoms fall into two groups so far as I have been able to study them. In one a fluorescent pigment occurs in solution in the vacuoles; inasmuch as these vacuoles are filled with an oil, which is lightly colored yellowish green by transmitted light, it may be inferred that the pigment affording the deep red fluorescence is in solution in the oil. The chlorophyll in these forms is not simultaneously observable as fluorescent, because of reflections. Particularly beautiful is *Meridion,* each cell of which contains a large and a smaller vacuole appearing to be set as gems in a golden-green setting.

Other species appear to contain no oil vacuoles, and the fluorescence is confined to the chloroplasts. These forms contain two fluorescent pigments, chlorophyll and a water-soluble red fluorescent pigment.[18] Upon heating, the latter disappears, and the chlorophyll, being demasked (Kohl, 1906), now appears as brilliant green granules. Here, as in the blue-green algae, there has probably occurred a disturbance of the chlorophyll colloidal complex, whereby the fluorescence is rendered invisible. The fluorescent color of these forms in the living condition is deep blood-red.

Spirogyra: This and other forms containing presumably only chlorophyll by way of fluorescent pigment are by no means as easily seen to be fluorescent

[16] Distance between turns of spiral 17 microns, width of spiral 19 microns, of cell 3.4 microns, the individual approaching 1 mm in length.

[17] Bright green (transmitted light) with large bright granules; width of spirals 12–13.6 microns, distance between turns 17 microns.

[18] This may be carotin, according to Kohl's (1906) view.

as those containing water-soluble fluorescent pigments. The difficulty arises again from the multitude of reflecting surfaces. Accordingly, the smaller and more delicate species (*S. porticalis*, e.g.) containing one or two chloroplasts and few granules are the best for observation. The most successful preparations have been made in cane sugar solution, which of course causes the cells to collapse. This very result, however, enhances the observability *per oculis* of the fluorescence. When seen, the chlorophyll band appears somewhat various in color, this resulting from the unavoidable mixture of reflected with fluorescent light. In its purity the latter is very deep blood-red, especially when seen in a chloroplast which lies athwart the axis of vision. This color varies from blood-red to brilliant vermilion more or less masked by the light reflected from granules. The lenticular body of the pyrenoid is not fluorescent. Judging from the transmitted light appearance we should expect that the globoidal mass within the lens would be fluorescent, and this sometimes may be seen, but not constantly.

On heating to boiling point, the chlorophyll is not rendered non-fluorescent, but it becomes more or less extruded into vacuoles which originate in the chloroplast, and these now contain the chlorophyll, or at least a derivative of it, which can be seen to be fluorescent without the aid of filters. In some species, however, filters are a necessary aid to observation.

Chantransia possesses a very pronounced orange fluorescence more or less irregularly red, especially in the spores. The chloroplasts are irregular bands having an olive-green transmitted light color. When first observed with the inverted light cone the fluorescence can be seen to be confined strictly to the chloroplasts. In the course of a few minutes, however, the light, probably by the heat engendered, causes the chloroplasts to lose their form so that the whole cell becomes filled with fluorescent pigment. Similarly, the plant becomes green upon heating and the yellow fluorescent pigment destroyed.

The relation of the pigment above described which conforms, of course, with previous knowledge, is seen most beautifully in germinating spores, as during germination there remain only a few small chloroplasts in the original spore cell.

Chloroplasts of Higher Plants: The treatment of chloroplasts with glycerine or cane sugar is necessary to keep them from disintegration which, however, appears not to proceed in water so uniformly nor is so rigidly conditioned by structure as has been thought by Timiriazeff and by Wager. In water or in very weak glycerine the chloroplasts take up water and form large vacuoles devoid of fluorescence, while in strong glycerine or cane sugar the chloroplasts appear to suffer shrinkage accompanied by extrusion of fluorescent drops, the brilliant granules which may always be observed remaining intact.

The observability of fluorescence by the means which I have described is nearly always more or less impeded by the presence of these brilliant granules which appear green. I have been inclined to believe from this observation that the chlorophyll occurs in the chloroplasts in two conditions, a suggestion already made by Stern. Since, however, the granules on extrusion from the stroma are white, we believe that their green appearance when seen *in situ* is due to the transmitted light color of chlorophyll in the surrounding stroma, and that therefore the granules do not contain chlorophyll. The fluorescent light emitted by the chloroplast is coterminous with the non-granular stroma. It is, therefore, rather easy to acquiesce with the somewhat generally accepted view that the chlorophyll in the chloroplast is associated with lipoid. The occurrence of fluorescent pigment in large oil drops requires explanation. Gaidukow observed these in *Vaucheria*. Whether these oil drops may be extruded as assimilatory substance either as a normal procedure or as the result of the contraction of the chloroplast by the glycerine or cane sugar, as the case may be, is still an open question. Upon mechanical disturbance these oil drops run together and become very conspicuous in the field, and have much the appearance of the drops of fluorescent substance derived from the blue-green algae when treated with cane sugar. It is quite possible, of course, that the pigment in the oil of *Vaucheria* is not chlorophyll at all, but may be similar to or identical with the pigment in the vacuoles of the diatoms. This idea is supported by the observation that one of the unicellular green algae, *Gloeocystis vesiculosa* (as seen in the photograph before you), which contains a red fluorescent pigment in the vacuole while, simultaneously, the chlorophyll does not appear fluorescent. In *Pleurococcus* this pigment extraneous from the chloroplast does not occur. Whether *Chlorella* studied by Stern conforms to this observation would be worth while to know in view of the observations and conclusions of that author.

In concluding, I may remark that this method of microscopic observation will most certainly add much interest to the study of green plants, and this, as I think you will agree when you have examined the preparations awaiting your pleasure, because of the astonishing and altogether remarkably beautiful pictures which these organisms, when illuminated by their own fluorescent light, afford. This interest is measurably enhanced on the reflection that the fluorescent pigments involved may all prove to be of much greater importance than at present supposed, chlorophyll excepted from the supposition. It would be leading us too far afield to consider, in this con-

nection, the possible significance of the physiological studies in the realm of photodynamics and their bearing on the nature of the chlorophyll mechanism,[19] but the opinion may be ventured that further attack, in which the water-soluble fluorescent pigments receive more extended and more critical study than they have as yet, will bring a rich victory.

Nor can one be aware of the discussions in the field of phototherapy, instancing, for example, the remarkable curative effect of light in rickets, without feeling that there exists some relation between this and the fluorescence of the blood pigment.

It may be added, also, that the taxonomist will find it to profit him to make use of the method for the finding and identification of the blue-greens. It is quite surprising with what ease one can find the organisms. For searching purposes alone, it is incomparable. Added to this is the fact that these organisms afford nuances of color which permit closely similar organisms to be separated and identified much more readily than when transmitted light alone is used. Furthermore, many of the grass-greens will be found to contain other fluorescent pigment than chlorophyll, and we are not compelled to await the outcome of the more tedious and time-consuming methods of the pure-culturist and biochemist, for the discovery of such organisms. We can now find the organisms by optical search, and, then, if it is desired, employ those methods with more direction. As I have already shown, too, there may be many organisms which do not contain fluorescent pigments, but which have not hitherto been regarded as members of the *Bacteriaceae* and perhaps which should not be so regarded, but which occupy a sort of intermediate position between these and the blue-greens. Other possibilities present themselves, but space prevents further discussion.

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[19] Discussions occur in Gicklhorn's 1914 paper and in Grafe's recent book, Chemie der Pflanzenzelle.

FRANCIS E. LLOYD
MCGILL UNIVERSITY

THE ECONOMIC VALUE OF GOVERNMENTAL SCIENTIFIC WORK[1]

THE subject that I have been asked to speak on is an interesting one to other persons than those who devote their lives to science. The economic value of the scientific work of the government is to some extent appreciated by the people of the country; I think, exactly to the extent that they come into contact with it and know about it. Perhaps, however, they do not realize that it is scientific work. There are various organizations of the government that perform services for the people, which services are based on scientific research—sometimes on very definite and exact knowledge, sometimes only on whatever state of knowledge has been reached after research has been pursued as far as it has gone, up to the present time. The people know the service they are getting. The western farmer knows something about the Bureau of Animal Industry that cures hog cholera, but it seems to me that the farmer does not think of it as scientific work; he thinks of it as a very valuable service which means dollars and cents to him. The southern cotton planter knows of the Bureau of Plant Industry and its progress in ridding him of the thing that threatens his welfare—the boll weevil. He may know that it is the result of scientific investigation, but he is more likely to think of it as a certain service that he needs on his plantation. Every shipper of meat in summer wants to know whether there is a hot wave coming that will require him to put more ice in his refrigerating cars. He depends on the Weather Bureau to give him that information. This is a service that is performed by the Weather Bureau and received by the people who hardly think of it as scientific work at all. Everybody knows that there is scientific work and that the government does it, but it is the idea of service that is most prominent in the minds of the people that receive it. The warnings that keep vessels in harbor when dangerous storms are coming are given out by the same bureau; warnings of frost that make fruit growers get their petroleum heaters out into the orchards. I shall not undertake to go through the various services performed by the Department of Agriculture, and I could not at all give a complete list of the services performed by the Bureau of Standards; I speak of certain things that are generally known. The farmers know certain scientific work of the Department of Agriculture and the manufacturers

[1] Address made at the dinner of the American Geophysical Union at its annual meeting.

know of certain of the services rendered by the Bureau of Standards. I wish everybody knew more, and I think one reason why everybody does not know more of the value of scientific work—well, perhaps it is because some of the scientists do not express themselves so that an ordinary man can understand them.

I have read, or attempted to read, scientific articles that I have no doubt were thoroughly intelligible to other scientists engaged in the same specialty (at least, I hope so) but not intelligible to an outsider who has only an interest in science as one of the fields in which the human intellect is at work. It is 300 years since Francis Bacon said with, I suppose, the egotism of youth, "I have chosen all learning to be my province." No man can do that now. But, after all, the all-round man is a fairly good sort of man to do the work of the world even in our own generation. No man can be a specialist in everything, but the man that does not know anything outside of his own specialty lives a very limited existence. He narrows himself and his own usefulness. General information is desirable, even though it falls short of the exact knowledge of the specialist.

If you want larger appropriations from Congress, tell us what you are doing in a way that will enable us to understand it. I think I speak for a good many members of Congress when I say that there is not only a willingness, but a desire, to go just as far along that line as public sentiment will permit. You can not appropriate all the money that is asked for all the purposes for which it is asked in these days. A study of appropriations has been made, and made very carefully, by Dr. Rosa, who guarded his statement so that it ought not to have been misunderstood, but yet it has been misunderstood and misused. When he went through the appropriations made by Congress from the United States Treasury for a period of years he estimated that in 1920 about 92 per cent. of the appropriations were for present or past wars. In that, of course, he included all payments of interest on the national debt, all pensions and compensations, all provisions for the World War veterans through the Veterans' Bureau as well as all appropriations for the War Department and the Navy Department except the non-military work, particularly the non-military work of the War Department in rivers and harbors. I think this percentage was 92½; about 6½ for general government purposes, leaving 1 per cent. for scientific work and education. This 1 per cent. was about $57,000,000 that year, out of a total of five billion six hundred and some million dollars.

Well, what was the United States Government organized for? To provide for the national defense especially, and, in things not reserved to the states, to promote the general welfare. The 13 states could take care of themselves pretty well except in the matter of national defense, and the principal thing that the United States Government was organized for was to defend the states against foreign enemies. Education was not thought of as a national activity, nor was the development of scientific knowledge.

Nevertheless, in that year in which $57,000,000 were appropriated by the government for all these services based upon science, and for education, the states and municipalities appropriated $1,039,000,000 for education. So it is not exactly fair to say that the representatives of the people of the United States spend 92 per cent. of the revenues raised by taxation for war, past and present and future, and 1 per cent. for scientific research and education. Nevertheless, while the duty of education, and even the promotion of scientific research, is not one of the chief purposes of the United States Government, it is one of the things that we can do and are permitted to do. The Constitution provides that Congress may levy taxes for three purposes only. Congress has power to levy taxes to pay the debts, to provide for the national defense, and to provide for the general welfare of the United States. The general welfare clause has been overworked. There are no restrictions on the right of Congress to pay the debts, but there are restrictions on the right to appropriate money to provide for the national defense. We can appropriate for the Navy for as far into the future as policy may seem to require, but for the army for only two years at a time. As a matter of fact, it is ordinarily for only one year. Appropriations for the general welfare also are restricted to certain matters enumerated in the Constitution. I confess I do not know exactly where to find the enumeration that covers scientific research, but the interpretation of the general welfare clause has been greatly extended in recent years. We do appropriate some money for scientific purposes and I hope we will appropriate more for these purposes in time to come; not only scientific work that results immediately in services of which I have given examples in some of the branches of the Government, but scientific work that seems now to have little prospect of economic value; pure research work. I think we ought to see far enough into the future to know that any such work will probably have an economic value in time to come. It is not very many years ago that we heard of the discovery by a German physicist of peculiar stresses in the ether to which the name Hertzian waves was given. Nobody thought then that this discovery would be of great economic value in the future, but now in almost every home that can afford it there is a radio receiving set catching messages which come by these same stresses. It never pays to lose a chance to learn anything that can be learned about the physical universe. It will have a

value when we have learned other things that fit with it and make it complete.

Now, as I said a little while ago, I wish every man engaged in scientific work could tell the story of what he is doing in such a way as to show to ordinarily intelligent men its possible relation to other things than his own immediate specialty, and its possible useful application, and I feel sure that we could get a backing in public sentiment which would show itself in the action of Congress by an increase of appropriations for that kind of work, to the very great advantage of our civilization. It is not the easiest thing in the world to convey a new idea to any mind. I suppose it is true, really, that no man can take in an absolutely new idea. The psychologists tell us of apperception, the coalescence of a new idea with the old state of mind which receives it—the assimilation of a new idea by the group of ideas already in possession. A place must be found in the framework of one's thinking where the new knowledge will fit, or perhaps the new knowledge must be distorted and considerably modified before it can possibly be taken in. I recall the story of a negro boy in Africa who became, I think, a clergyman afterward in his native country. In his stripling days he had been one of the bearers in the caravan of David Livingstone. Livingstone was a man who sat with his servants around the camp fire and talked with them not merely of religion, though he was a missionary, but of anything that would interest them and furnish common ground between his mind and theirs. This negro boy had learned to have great respect for and confidence in the white man, but, as he told the story years afterward, his confidence was seriously shaken when Mr. Livingstone tried to get him and the other black men around the camp fire to believe that in England they had tea kettles that could pull wagons. It was not until many years afterward, while himself riding in a railway car, that he suddenly recalled with amusement the result of his attempt to find a place for the locomotive in the group of ideas already in his mind. Perhaps you may find men in Congress, and elsewhere as well, who can come no closer to what you are trying to tell them about your specialty than that negro boy did to the unfamiliar truth that Livingstone was trying to convey to him. But try it; it can be done; it has been done.

I think I may be pardoned if I say that I have a sixteen year old boy who, about two years ago, came across a scientific book that aroused his interest, and I think that book is going to influence his choice of a profession in life. A few years before some one had given him a toy set known as a chemo-craft set. It contained a few chemicals and a little pamphlet describing some experiments that were spectacular and would attract the attention of a boy. His interest, aroused in that way, continued. About two years ago he saw on my desk a book called "Creative Chemistry" which he could read and understand. Science needs a press agent, and in Washington you have him. I believe that boy is going to be influenced all his life and his tastes will be developed along the lines of the book written by Dr. Slosson.

That is an example of what I have been trying to say. It is necessary to make your work understandable to the man who is not a specialist in your line, but who has some intelligence. You can not express everything with perfect accuracy without using technical language, but most men can not carry away a thoroughly accurate impression even if a matter is minutely and accurately explained; so sometimes a teacher has to content himself with giving an approximate idea of the truth. Let us speak the English of the streets, and give the ordinary man a chance to understand what we are doing.

H. W. TEMPLE

WASHINGTON, D. C.

SCIENTIFIC EVENTS

BRITISH EXPEDITION TO EAST AFRICA

ACCORDING to an article in *London Times* during the years that part of East Africa was under the jurisdiction of the Germans a large number of specimens of a gigantic dinosaur were raised and transported to Berlin. For the past four or five years the trustees of the British Museum have had under consideration the proposal to send a small expedition to East Africa, with the view of exploring the fossil remains that occur there, especially these large dinosaurs, as it would be of the greatest interest to correlate them with similar remains which have been known for many years from the Jurassic rocks of Wyoming.

Sufficient funds have now been got together to enable a start to be made, and early last autumn the trustees secured the services of Mr. W. E. Cutler, of the University of Manitoba, to lead the expedition. He sailed from Marseilles on February 28.

Mr. Cutler has for many years had an unrivaled experience of collecting for the British Museum and other museums large dinosaurian and similar fossils in North America, and is therefore conversant with the methods of extracting the specimens from the matrix and packing them in such a way as to withstand the strains and stresses of the journey to the museum.

Since it was desirable that Mr. Cutler should have in the party at least one white assistant, the trustees arranged for Mr. L. S. B. Leakey, of St. John's College, Cambridge, to accompany him. He was born in Kenya Colony, and his home is still there, his father being a clergyman near Nairobi. His knowledge of

the natives and their languages will promote the smooth working of the expedition. So far as opportunity affords and time permits, Mr. Leakey will collect other natural history specimens, such as birds, mammals and plants.

The site which was originally worked by the Germans, and where the large dinosaur known as *Gigantosaurus* was found, is at Tendaguru, about 50 miles, or four days' march, slightly west by north of Lindi, which is an open roadstead near the southern extremity of Tanganyika. Large steamers call only at Dares-Salaam, but there is a fairly frequent coastal service between that port and Lindi. The site has in the course of years become overgrown with vegetation, and the neighborhood is almost uninhabited, but no great difficulty is anticipated in opening up the site again.

There is another site about two miles east, in the Mbemkuru valley, where remains of *Gigantosaurus* were discovered by Major Pretorius; this will also be investigated. The working season extends from early May until the end of December. During the wet season, when about 17 inches of rain falls, exploration and transport are practically impossible.

Sir Horace Byatt, the Governor of Tanganyika Territory, has promised such help and facilities as the administration can provide. The trustees hope that funds will permit and results warrant the exploration being continued for at least two seasons.

THE USES OF WATER

THE third symposium of the year at Harvard University, under the auspices of Gamma Alpha, the scientific society, which had for its subject "The Nature and Uses of Water," was held on March 4, in the Harvard Union.

Professor Alexander McAdie, meteorologist and director of the Blue Hill Observatory, spoke about water in the air, his title being "Rain, hail and snow." The talk was illustrated with lantern slides, and Professor McAdie made one experiment, that of weighing the collective breath of the audience. He discussed also the causes of floods and conditions determining droughts, and various schemes for making rain.

Professor Reginald A. Daly considered the geological history of the ocean, with the title "Ancient and modern oceans." He dwelt briefly on the origin of the visible water of the globe, the changes in the composition of the ocean and in its extent, with a glance at the problem of the distortion of the earth's body, at tidal friction and its consequences.

With the subject "Man's control of water," Dr. George C. Whipple, professor of sanitary chemistry in the Harvard Engineering School, showed how large a part water has played in man's existence on the earth, how man's control of water has advanced with engineering science and led to stabilization of population and the opening up of large areas for habitation. He took up also control of the quality of water, involving chemistry and water purification, and finally the establishment of legal principles because of man's use and control of water.

The symposium was held at 8 p. m. in the Harvard Union, under the auspices of Gamma Alpha, the scientific society, and was open to the general public.

THE MANUFACTURERS ASSOCIATION OF CONNECTICUT AND YALE UNIVERSITY

A PLAN for the cooperation of Yale University and the Manufacturers Association of Connecticut in industrial research and educational work has been developed under the leadership of a committee composed of John H. Goss, of Waterbury; E. Kent Hubbard, of Hartford; L. S. Tyler, of New Haven; Howell Cheney, of South Manchester, and Samuel Ferguson, of Hartford, working with a committee representing Yale University, consisting of Dean Charles H. Warren, Professor L. P. Breckenridge (later succeeded by Professor S. W. Dudley) and Professor F. E. Spaulding.

The plan for cooperation aims to enable the industries of the state to secure greater access to the facilities that the university possesses for the carrying on of scientific and technical research, and for manufacturers to secure more easily the services of young men technically trained along the lines of special importance to their particular industries. On the other hand, it aims to afford the university an opportunity to render a more effective service to the community; to bring its students and staff into closer contact with the practical applications of science to industry through the investigation of problems arising in the industries; and to afford its students better opportunities for securing practical experience by actual work under supervision in manufacturing plants during vacation time.

For many years past the university, chiefly through its scientific and engineering departments, has cooperated with individual manufacturers in carrying out technical and scientific investigations in a number of different fields. These investigations have been carried out by members of the staff, or under their direction, and have frequently furnished results of value to the particular industry concerned and to science and technology in general.

It has not, however, been generally known, particularly among the smaller manufacturers more remote from the larger industrial centers, that such work was being done or that it could be done. Under the plan developed by the university and the association it is

now proposed to direct the attention of all industrial concerns throughout the state to the fact that such facilities are available and to emphasize as strongly as possible the benefits to be derived from research.

The main features of the plan include provisions for research; use of the university library facilities; employment of scientifically and technically trained Yale graduates; the training of specially qualified young men sent by manufacturers to the graduate school of the university; the loan of equipment to the university for use in training students; and the inspection of factories, summer employment of students and cooperative education, as a part of technical and semi-technical courses at the university.

The provision for research will be worked out under the plan as follows: a member of the Manufacturers Association desiring the investigation of a problem may send his inquiry to the association headquarters at Hartford. At the discretion of the research committee of the association the problem will be submitted to a committee acting for the university, and arrangements will be made to carry out the investigation either at the university or at the plant of the party proposing it. The research work, under the direction of well-known experts in a variety of fields, will include economics and finance, administration and management, transportation, applied psychology, public health, bacteriology, chemistry and chemical engineering, physics, mining and metallurgy, and civil, electrical and mechanical engineering.

Under the plan industrial concerns are to have access to the library facilities of the university for obtaining statistics and information concerning technical processes that usually can not be obtained in public libraries.

The attention of manufacturers is to be directed to the possibility of securing scientifically and technically trained young men through the university Bureau of Appointments, which assists in placing Yale graduates in positions for which their training fits them.

In order that the university may train students in the designing and use of special machinery and apparatus, arrangements will be made through the committee for the loan of equipment to the university. Tests will be made of such equipment, and the results will be available to the company furnishing it.

The cooperation of manufacturers with the committee will be sought in developing plans for summer employment and cooperative education. The advantages which will accrue to industry through such cooperation are believed to be great.

Students will be given the opportunity to visit plants throughout the state as a part of technical and semi-technical courses.

CHEMICAL INDUSTRY

THE progress of industry in the United States is more and more being bound up with the progress of chemical science, and "it is absolutely necessary for both the banker and the manufacturer to appreciate this if they are to avoid stagnation," according to Dr. John E. Teeple, of New York, treasurer of the American Chemical Society.

Addressing the Delaware Bankers' Association recently Dr. Teeple said that more than one half of the manufacturers of this country, with a total value exceeding $62,000,000,000, were dependent upon chemistry. So rapidly was chemistry's invasion of industry spreading, he added, that this proportion was constantly becoming larger.

He named six groups—textiles, iron and steel, leather, paper, ceramics and glass, metals and metal products—with a production valued at more than $33,000,000,000 which have a definite chemical basis. Chemical and allied products, he said, have risen in value from $750,000,000 in 1899 to more than $6,000,000,000 in 1924.

The chemical industry now ranks fourth, being outranked only by food, iron and steel and their products, and textiles, in all of which chemistry is an increasingly important factor.

Stressing the importance of research in any industry, Dr. Teeple said:

> Given any chemical industry to-day, I would rather judge its future by its fixed attitude toward research than by its fixed assets, its working capital or its past earning power.
>
> In 1915 there was no potash industry here. We wanted one suddenly and the price of potash was high. In 1918, forty-four plants were actually producing potash as a main product, not as a by-product of some other operation. Just one of these forty-four plants deliberately organized a research department and kept it constantly at work making a complete and fundamental study of its problems.
>
> To-day potash is back to pre-war prices or lower, and only one of the forty-four plants is operating in competition with French and German potash. This one plant had no particular advantage of location, raw materials, patented process, or knowledge of the industry over many others, but its directors had the foresight and its financial backers had the nerve to organize research and put up the money for it month after month in good times and in bad ones.

THE HISTORY OF SCIENCE SOCIETY

THE History of Science Society, to which reference has already been made in SCIENCE, has been definitely organized with an initial membership of about three hundred. The officers for the current year are as follows:

President, L. J. Henderson, Cambridge.

Vice-presidents, James H. Breasted, Chicago; Florian Cajori, Berkeley, Calif.

Secretary, David Eugene Smith, New York.

Treasurer and Assistant Secretary, Frederick E. Brasch, Washington, D. C.

Chairman of the Committee on Publications, George Sarton, Cambridge, Mass.

The executive body consists of the officers and a council of fifteen members, as follows: Isaiah Bowman, New York; E. W. Brown, New Haven; Henry Crew, Evanston; David Starr Jordan, Stanford University; George Ellery Hale, Pasadena; Berthold Laufer, Chicago; Duncan B. Macdonald, Hartford; J. Playfair McMurrich, Toronto; John C. Merriam, Washington; George F. Moore, Cambridge; Edgar F. Smith, Philadelphia; M. Rostovtsev, Madison; Lynn Thorndike, Cleveland; William H. Welch, Baltimore; Frederick J. E. Woodbridge, New York.

The membership dues are five dollars a year, which includes subscription to *Isis,* the official journal of the society. Applications for membership should be sent to Professor David Eugene Smith, 525 West 120th St., New York City.

SCIENTIFIC NOTES AND NEWS

A PORTRAIT of Edward C. Pickering, director of the Harvard College Observatory from 1877 until his death in 1919, is given as a frontispiece to the fourth volume of the Publications of the American Astronomical Society, which contains the collected papers read at the annual meetings from 1918 to 1922.

PROFESSOR ALBERT EINSTEIN has been awarded by the assembly of Amsterdam University the gold medal of the Holland Society for the Progress of Natural Science.

MME. CURIE in honor of her work with radium has been granted the freedom of the city of Warsaw.

THE following official announcement has been made by the trustees of the University of Pennsylvania in regards to the statues of former provosts to be erected on the campus.

The campus of the University of Pennsylvania will be made more interesting and attractive in the near future by the erection of statues of former Provost Charles C. Harrison and of his immediate successor in office, former Provost Edgar F. Smith. At a recent meeting of the board of trustees of the university, the Hon. John C. Bell, who has for many years been a member of the board, and closely identified with the development of the interests of the university, under the administration of these provosts, requested permission of the board to erect the statues at his own expense.

It is appropriate that the memory of men who have distinguished themselves by unselfish service to a great university, and by qualities of leadership that have resulted in the development of the institution into a wider usefulness should be perpetuated not only in the hearts of the men who know them, but also by the visible, tangible presentment of statues, upon which generations that knew them not in flesh may look for inspiration. The precise location of these memorials has not yet been determined, but the fact that they are to be erected is of interest to all who respect the achievements of men, whose contributions to the life of the community, and particularly to the University of Pennsylvania, have marked them out as those who have served faithfully and well in their day, and have left the institution enriched by their presence in it.

AT a recent meeting of the American Psychological Association the following resolution was passed:

Whereas, Professor Joseph Jastrow, the first secretary of the American Psychological Association and its president in 1900, was appointed to a chair in psychology in the University of Wisconsin in 1888, and has occupied this position for an unbroken period of thirty-five years, a record unique in the history of our science, therefore,

Resolved, That the American Psychological Association, meeting at Madison, presents its sincere congratulations to the University of Wisconsin on the long and distinguished service rendered by Professor Jastrow to it and for the advancement of psychology.

THE HONORABLE WILLIAM KELLY, for many years chairman of the Board of Control of the Michigan College of Mines, is the newly installed president of the American Institute of Mining and Metallurgical Engineers. Mr. Kelly is also one of the councilors appointed by the institute to represent it in advising the Board of Investigation and Coordination created by the society for the Promotion of Engineering Education. The work of this board was recently financed through a grant by the Carnegie Corporation.

AT the annual meeting of the Philadelphia Pathological Society, Dr. Edward B. Krumbhaar was elected president; Dr. Eugene L. Opie, vice-president, and Dr. Baldwin H. E. W. Lucke, secretary-treasurer.

CAPTAIN C. J. P. CARE has been elected president of the Royal Meteorological Society. The vice-presidents are Dr. C. Chree, Mr. J. S. Dines, Dr. A. Crichton Mitchell and Dr. G. T. Walker.

SIR MALCOLM MORRIS has been appointed chairman of the Radium Institute, London, in succession to the late Sir Frederick Treves. Sir Humphry Rolleston has accepted a seat on the committee of the institute.

THE following advisory committee has been appointed to administer the funds of the British Empire Cancer Campaign: Sir John Bland-Sutton, Dr. H. H. Dale, Sir Richard Garton, Dr. F. Gowland Hopkins, Dr. Robert Knox, Sir William Leishman, Professor C. J. Martin, Dr. Robert Muir and Sir Humphry Rolleston.

THE gold medal of the British Institution of Mining and Metallurgy has been awarded conjointly to Herbert William Gepp, M.Inst.M.M., and Gilbert Rigg, M.Inst.M.M., in recognition of their joint and individual services in the advancement of metallurgical science and practice, with special reference to their achievements in the treatment of complex sulphide ores, and in the development of the electrolytic process for the production of zinc in the Commonwealth of Australia.

SIR OTTO JOHN BEIT has been made a baronet for services rendered to the Imperial College of Science and Technology at South Kensington.

THE National Academy of Sciences has made Professor Harold Hibbert, Yale University, New Haven, Conn., a grant of $400 from the Bache Fund and $300 from the Cyrus M. Warren Fund, for the purchase of apparatus for the determination of ultraviolet absorption spectra in connection with the constitution and properties of carbohydrates and polysaccharides.

DR. FRANCIS A. BRACKETT, for fifty years instructor in the Dental School of Harvard University, has resigned the professorship of oral pathology, and becomes professor emeritus on September 1.

DR. CHRISTOPHER C. PARNALL, superintendent of the hospital and professor of administrative medicine at the University of Michigan Medical School, Ann Arbor, has resigned, effective on June 30.

DR. GEORGE H. BIGELOW, director of the Pay Clinic of the Medical School of Cornell University, son of Dr. Enos H. Bigelow, president of the Massachusetts Medical Society, has been appointed to the position of director of the Division of Communicable Diseases in the Massachusetts State Department of Public Health.

FRED J. MILLER, of Center Bridge, Pa., past-president of the American Society of Mechanical Engineers, has been appointed a member of the Public Service Commission by Governor Pinchot of Pennsylvania. Mr. Miller will conduct a survey of the electrical power service of the state with a view to bringing to the farm population the benefits of electricity. The appointment is for a ten-year term at a salary of $10,000 a year.

W. M. H. GREAVES has been appointed chief assistant at the Royal Observatory, Greenwich, following the appointment of Mr. Spencer Jones as H. M. Astronomer at the Cape of Good Hope.

E. BALLARD, of Bristol University, has been appointed cotton entomologist to the Commonwealth Government of Australia.

GEORGE H. JOHNSON has been appointed to the fellowship maintained in Mellon Institute of Industrial Research of the University of Pittsburgh by the Laundryowners National Association. His principal assistant will be Miss Mary M. Danley, an industrial fellow of the Mellon Institute, and his advisers will be Dr. W. F. Faragher, assistant director of the Mellon Institute, and Dr. A. F. Shupp, manager of the American Institute Laundry, Joliet, Ill.

THE Canadian Fellowship of Chemical Science valued at £600 has been awarded to Edward H. Boomer, a graduate of McGill University, Montreal. Dr. Boomer obtained the degree of Ph.D. in 1923 and was awarded the Ramsay Memorial scholarship, under the terms of which he has been working at Cambridge University.

PROFESSOR C. V. L. CHARLIER, of the University of Lund, Sweden, will arrive in America by the middle of March for a stay of some months. He will visit the observatories and give lectures at some of the universities, including two public lectures at the University of Chicago on April 3 and 4 on "Statistics and natural philosophy."

SEVERAL illuminating engineers are making a three months tour of the United States to study American lighting methods. The party consists of J. N. Stephens, W. H. Williams, W. J. Willner, C. Hughes, G. A. Percival, F. W. Wilcox and George Franklin of London; J. Rosenthal of Berlin, and the American engineers, C. A. Atherton of Cleveland and A. L. Powell of Newark, N. J., who will return to Europe with the visitors.

DR. RICHARD C. TOLMAN, professor of physical chemistry and mathematical physics at the California Institute of Technology, addressed the members of the Southern California Section of the American Chemical Society on February 21, at the institute, on "Newer theories of the rate of chemical reaction."

PROFESSOR A. Ll. HUGHES, head of the department of physics at Washington University, lectured before the graduate students and staff of the physics department of the University of Iowa on February 13 and 14 on "Effects between collisions of electrons and molecules" and "Saha's theory."

THE program of the Philosophical Society of Washington for the meeting on March 8, was as follows: C. LeRoy Meisinger, "Barometric reductions in the plateau region of western United States"; E. W. Washburn, "A calorimeter for measuring heat effects at high temperatures."

THE fifth of a series of orations in celebration of the centenary of Birkbeck College, University of London, was delivered by Dr. W. Bateson, director of the John Innes Horticultural Institution, on March 12. His subject was "Progress in biological science."

DR. J. A. MURRAY, director of the Imperial Cancer Research Fund, delivered the first of four public lectures on cancer at St. Thomas's Hospital on February 21.

THE laboratory for research in colloid chemistry and physics, which has been founded at the University of Manchester, England, by merchants of the county, was formally opened on January 23. The laboratory is named after Thomas Graham, and has five rooms equipped for research work. Professor D. C. Henry, lecturer in chemistry at the university, is in charge.

THE *Journal* of the American Medical Association reports that the former laboratory of Professor Röntgen in the Physical Institute of the University of Würzburg has been named the Röntgen Memorial Room. A large part of his original apparatus is still set up, and most of it was made by him. Here are the first röntgen tubes, and the original photographs that led to his discovery. A cabinet contains the medals and other presentations received by Röntgen from the Nobel Foundation and various institutions. By his work table is a complete collection of his publications. There is also a bust of Röntgen in the room.

GEORGE HERMANN QUINCKE, one of the most distinguished of German experimental physicists, long professor at Heidelberg, died on January 13 in his ninetieth year.

JEAN M. E. STEPHAN, for many years director of the Marseilles Observatory, died on December 31 at the age of eighty-six.

CAPTAIN T. H. TIZARD, F.R.S., formerly assistant hydrographer to the British Admiralty, died on February 17, aged eighty-four years.

THE Optical Society of America has planned to publish a complete translation of the third edition of Helmholtz's *Handbuch der physiologischen Optik*, edited by James P. C. Southall, professor of physics in Columbia University. The work will be issued in three volumes approximately in the same style as the original German edition, with the same illustrations, plates, etc. The first volume is now in press and will probably be ready by June, 1924. The other volumes will follow as soon as they can be prepared. The edition is limited to one thousand copies. The price will not exceed $7 a volume. In order to insure getting all three volumes, orders should be sent without delay to Professor F. K. Richtmyer, managing editor of the *Journal of the Optical Society and Review of Scientific Instruments*, Cornell University, Ithaca, New York.

THE United States government has appealed from the decision of the United States District Court which was rendered adversely recently by Judge Hugh M. Morris in its suit for the return of numerous German dye patents by the Chemical Foundation, Inc. The appeal is signed by James M. Beck, solicitor-general of the United States; Attorney-general Daugherty and other federal counsel. Seventeen allegations of error are made in the appeal, which is general rather than specific, and concludes: "The court erred in each and every one of its conclusions of law and fact contained in its opinion in this case made a part of the record."

UNDER the auspices of the New Haven Section of the American Society of Mechanical Engineers, a get-together meeting of the engineers of Connecticut will be held on March 18, at the Hotel Garde, New Haven. Following a dinner at 6:30 p. m., a meeting will be held which will be addressed by Dr. Ira L. Hollis, president of the Worcester Polytechnic Institute, on "The part that production has played in the permanency of nations," and by John L. Davis, of New Britain, on "America—the land of opportunity."

A PLEDGE of $5,000 toward the preparation and publication of the International Critical Tables of Physical and Chemical Constants has been made by the Western Electric Company.

UNIVERSITY AND EDUCATIONAL NOTES

CONTRACTS for the new science building at St. Stephen's College, Annandale-on-Hudson, have been let by the board of trustees. The building will cost about $120,000. Excavation for the science building and also for a new dormitory will be started as soon as the frost is out of the ground. It is expected that the cornerstone will be laid on commencement day.

MRS. ROBERT L. REA, of Chicago, widow of Dr. Robert L. Rea, for 30 years surgeon-in-chief of the Pennsylvania Railroad, has given to Northwestern University medical school $100,000 with which to establish a professorship in anatomy.

THE trustees of the Rockefeller Foundation have offered the University of Oxford a gift of £75,000 for the development of the department of biochemistry.

LORD GLANELY, in resigning from the office of president of the University College of South Wales and Monmouthshire, Cardiff, has supplemented his previous donations to the college funds by a gift of £12,500, bringing his contributions to a total of £65,000.

THE Bausch and Lomb Optical Company of Rochester, N. Y., has recently presented to the Department of Physics in Columbia University a col-

lection of optical apparatus and machinery, for instruction and research, particularly in applied optics, optometry and physiological optics. On February 29 an exhibition of the apparatus was held in Fayerweather Hall. Mr. Adolph Lomb himself was present and also Mr. Max Poser, of the Bausch and Lomb Optical Company. President Butler accepted the gift on behalf of the trustees of the university and Dr. Herbert E. Ives, president of the Optical Society of America, delivered an address on modern progress in physiological optics.

DR. PHILIP FRANKLIN, instructor in mathematics at Harvard, has been appointed to fill the vacancy in the mathematics department at the Massachusetts Institute of Technology caused by the death of Professor Joseph Lipka.

THEODORE H. DILLON, professor of electrical engineering at the Massachusetts Institute of Technology, has been appointed to the chair of public utility management in the Graduate School of Business Administration of Harvard University.

DR. J. E. HOLLOWAY, known for his work on the ferns of New Zealand, has been appointed lecturer on botany in the University of Otago, Dunedin.

DISCUSSION AND CORRESPONDENCE

PROPORTIONS OF DEFECTIVES FROM THE NORTHWEST AND FROM THE SOUTHEAST OF EUROPE

THE report of the Committee on Selective Immigration of the Eugenics Committee of the United States of America, published extensively in the newspapers, and recently by the *Eugenical News* (February), contains the following statements:

> Dr. Laughlin's studies bring out another very striking and important fact, *viz.*, that immigrants from northwestern Europe on the whole contribute far less in proportion to our alien socially inadequate institutional population than do those from southeastern Europe.
>
> A percentage limitation based on the census of 1890 would therefore not only reduce (1) the inflow of unskilled "cheap" labor, but would also greatly reduce (2) the number of immigrants of the lower grades of intelligence and (3) of immigrants who are making excessive contribution to our feeble-minded, insane, criminal and other socially inadequate classes. Percentage limitation based on the 1890 census, therefore, is the simplest, most logical and most effective means readily at hand for accomplishing all three of these very necessary things.

The proposition numbered (3) is a deduction from the first sentence quoted, but it is an illegitimate and incorrect one; and the first sentence quoted is enlightening only when the precise conditions on which it is based are understood. The proportion of "inadequates" contributed by northwestern Europe on the one hand, by southeastern Europe on the other hand, depends on the relative numbers present from particular subdivisions of those regions. The different subdivisions give extremely different proportions of inadequates. Thus, from northwest Europe, according to Laughlin, the proportion of inadequates yielded by Ireland is almost twice that yielded by Germany. It is obvious that the proportions contributed by northwestern Europe will be extremely diverse, depending upon whether the immigrants from that region are preponderatingly of such a type as that coming from Ireland, or of such as that coming from Germany. Parallel statements may be made for the diverse groups coming from southeastern Europe; Austria-Hungary, for example, shows the smallest proportion of defectives yielded by any of the major sources of immigration.

Now, the relative numbers of the different nationalities present in our European-born population of 1890 is extremely different from that of 1910; so much so that deductions based merely upon the relative proportions from northwest and southeast Europe in the two cases yield erroneous conclusions. If Laughlin's "quota fulfilments" are accepted as representative for the diverse groups,[1] the change to the 1890 percentage basis does not, other things being equal, tend to reduce the number of institutional socially inadequates. This is due mainly to the fact that in 1890 Ireland, which yields much the highest proportion of inadequates of any of the major groups, constituted in 1890 twice as great a proportion of our European-born population as it did in 1910. Laughlin's figures, if taken as typical, enable us to compute the respective numbers of institutional inadequates that would be contributed by two equal European-born populations constituted one as in 1910, the other as in 1890. I have carried out this computation; the results are set forth in the volume of hearings recently published by the congressional committee on immigration (pp. 512–518). It is there shown that on the basis of Laughlin's findings a European-born population constituted as in 1890 would contribute practically exactly the same number of institutional defectives as an equal European-born population constituted as in 1910. The proportions of the different kinds of defectives would be diverse in the 1890 combination; the number of insane would be 5.7 per cent. greater; of dependent 57.1 per cent. greater; of epileptic 3.0 per cent. greater; while the

[1] Laughlin's data and conclusions have been subjected to destructive criticism by R. R. Lutz (Hearings of the Committee on Immigration 1924, pages 250–283), and John M. Gillman (*Ibid.*, pp. 540–550), but these criticisms seem not to affect directly the data as to the relative proportions of defectives derived from different European-born groups.

number of criminals would be 42.4 per cent. less; of feeble-minded 20.9 per cent. less; of tuberculous 19.6 per cent. less. These increases and decreases in the different classes offset each other, so that for all classes of inadequates together the number from the 1890 European-born population is merely 0.9 per cent. greater than from the 1910 population. There appears, then, to be no basis in Laughlin's studies for the statement numbered (3) quoted above from the report of the immigration committee.

H. S. JENNINGS

THE JOHNS HOPKINS UNIVERSITY

THE POLICY OF THE SIGMA XI IN REGARD TO STATE COLLEGES

IN a recent number of SCIENCE (October 7, 1923) the writer made the statement that "the policy of the Sigma Xi has been to refuse the granting of chapters to state colleges." The statement was made with the knowledge that only two state colleges have been granted chapters of the Sigma Xi and upon the assumption that other state colleges had petitioned for chapters and been denied. The inference follows that state colleges, due to their nature or class or on account of a prejudice, have less chance of being granted a chapter of the Sigma Xi than do state universities. The truth of the statement as made has been questioned by some and affirmed by others. The detailed information necessary for the formation of a definite opinion regarding the policy of the Sigma Xi is not available. However, certain available facts serve to indicate the policy of the Sigma Xi and are herewith set forth.

The president and secretary of the Sigma Xi, through personal communications, state that it is not the policy of the Sigma Xi to discriminate against any class of institutions, that all petitions for chapters receive the same serious investigation and consideration irrespective of the nature or class of the institution.

There is nothing in the constitution or appendices to the constitution of the Sigma Xi to indicate a prejudice against state colleges. The policy of the Sigma Xi, as indicated by the constitution, is that a chapter may be established at any educational or research institution in which scientific research is cultivated and promoted, but that great care should be observed in establishing chapters and that the aims of the Sigma Xi will best be obtained by a strictly conservative policy. Obtaining a chapter requires the approval of the executive committee and a three fourths vote of the convention. It is obvious that when an action is determined by voting no constitution can predetermine the action.

Only two of the forty chapters of the Sigma Xi are held by state colleges. This fact has been advanced by some as evidence that the policy of the Sigma Xi is unfavorable to state colleges. It has been advanced by others as conclusive evidence that the Sigma Xi does not discriminate against state colleges, that the policy of the Sigma Xi is unfavorable to state colleges only to the extent of requiring research standards that the state colleges do not have.

We are justified in assuming that the executive committee is impartial in considering applications for chapters. But the fact remains that state colleges, with but two exceptions, have not been granted chapters. Why have not more state colleges been granted chapters of the Sigma Xi? Have they failed to petition for chapters, or have they failed by virtue of their function or otherwise to meet the requirements? The correct answers to these questions are worthy of consideration but can not be given by the writer.

The State College of Washington has never petitioned for a chapter of the Sigma Xi. I believe the reason has been that chapters, with one or two exceptions, were not being established in other state colleges and there was no basis for determining in advance what the result of such a petition would be. The State College has formed a research group known as the Research Council. This has been effective in stimulating research.

If the state colleges can not meet the requirements set for the granting of chapters of the Sigma Xi, wherein do they fail? Only the executive committee can answer this question. They do not fail because of their function which includes both instruction and research. The object of the Sigma Xi is to encourage original investigation. The requirements for membership set by the Sigma Xi deal with research. A full statement setting forth wherein state college and other educational institutions fail in research attitude, facilities or production will be of inestimable value.

Those institutions which can not meet the requirements set by the Sigma Xi need an active research organization more than those institutions in which research has been developed to the highest degree. The former need aid and encouragement. Will research be furthered more by granting them membership in the Sigma Xi now or by holding up before them the promise of membership when they have fulfilled certain requirements? The Sigma Xi has wisely given an affirmative answer to the latter question. The research men in those institutions which have been denied chapters of the Sigma Xi and in those institutions which have not applied for chapters should form one or more active organizations. Such institutions need and there is no reason for their being without a scientific society of such nature

and standing as to effectively stimulate research. Production of research is the important thing, not the acquisition of a chapter of the Sigma XI. Some of the most advanced institutions in regard to research, such as Harvard, Johns Hopkins and Princeton, do not have chapters of the Sigma Xi. We are justified in assuming that they have developed effective substitutes.

The existence of a research organization may be the deciding factor when application is made for a chapter of the Sigma Xi. If a number of Sigma Xi members are present these can form a Sigma Xi Club. "Such clubs have all the powers of chapters except that of electing to membership and furnish a simple and effective means of testing the environment to determine whether it is adapted to the establishment of a chapter of the society." In the opinion of the writer Sigma Xi Clubs do not satisfactorily meet the needs of the situation in educational institutions. If it is advisable in the interests of research for the Sigma Xi to offer the reward of a chapter to the institutions which measure up to certain standards it is equally desirable that the research organizations in colleges offer the reward of election to membership to those individuals who have made achievements in research.

VICTOR BURKE

PULLMAN, WASHINGTON

SIGMA XI has no policy in regard to state colleges. It has no policy in regard to state universities, privately endowed universities, technical schools, or any other *group* of institutions. Its one object is the promotion of research, and in its work covering nearly four decades it has tried to maintain the same unbiased attitude as does any *real* scientist toward the investigation in which he is engaged.

Election to membership is based on scientific achievement, actual or potential, and on that only. Were *every* student pursuing scientific studies elected to membership the society would soon become inert and purposeless. In making elections, the line is drawn at such a point as will, in the judgment of the society, result in the greatest possible contribution to the objects of the society.

The granting of a charter likewise is based on the scientific achievement, actual or *potential,* of the petitioning institution, *and on that only.* Were each institution of higher education in the country granted a charter at present, the society would be unable to maintain its high standards either as regards ideals or accomplishments. The line must be drawn somewhere, but in drawing the line there has *never been the suggestion* that any class of institutions should be excluded. The chapter roll of the society is as cosmopolitan as is its membership.

I repeat: Sigma Xi has no policy in regard to state colleges.

F. K. RICHTMYER,
President

QUOTATIONS

THE AMERICAN CHEMICAL SOCIETY AND THE AMERICAN ASSOCIATION

THE American Association for the Advancement of Science held its seventy-eighth meeting, celebrating the seventy-fifth anniversary of the association, at Cincinnati. The local sections of the American Chemical Society of that region cooperated with Section C, having been encouraged to do so by a vote of the council at the Milwaukee meeting. There are among our members many who regret that circumstances have made it advisable for the American Chemical Society to hold its meetings independently of the American Association for the Advancement of Science, and who have felt that more should be done to assist in the work of Section C than has been possible in late years.

At Cincinnati it was fully demonstrated that the intersectional meeting plan could be put into operation with Section C to mutual advantage. The result was not only a program of unusual merit, but an attendance which must have been gratifying to those responsible for the arrangement. The papers presented covered a wide range of subjects. The attendance was good at all the sessions, the discussion interesting, and on the whole the experiment was a success. We commend the plan to those local sections where future meetings of the American Association for the Advancement of Science will be held and assure them that it is possible to attract to these meetings many of our leading chemists.—*Industrial and Engineering Chemistry.*

SCIENTIFIC BOOKS

Bibliographical History of Electricity and Magnetism. By PAUL F. MOTTELAY. London. Charles Griffin & Company, Limited, 1922, pp. xix, 673.

THE history of electrical science falls somewhat naturally into three chapters. The first deals with electrostatics and magnetism, beginning in 1600 with the appearance of Dr. Gilbert's "De Magnete" and ending in 1800 when Volta's cell was reported to the Royal Society of London; the second period covers the rapid development of the Voltaic cell and the science of electrolysis, which took place during the first quarter of the nineteenth century; the third begins with the discovery of electromagnetism—1820 and 1831—and extends to the present. The volume under review deals mainly with the first two of these chap-

ters, although its first 80 pages are devoted to all the electrical and magnetic references from 2637 B. C. to 1600 A. D.—a period of four millenniums in which the only discovery of importance is that of the mariner's compass.

The general plan of Dr. Mottelay's work is to consider all the publications which have anything to do with electrical science, to arrange them in chronological order, and to indicate briefly the import of each paper. The date associated with each author is that of his first important publication. Each name is followed, as a rule, by one or two brief biographical notes, then by a statement of the author's new contribution to knowledge, often accompanied by a quoted opinion as to the value of this contribution, and finally comes a list of references to books, treatises and periodicals which mention this man's work. So much for the general scheme.

The reader comes to the text, well introduced by a foreword from Sir Richard Glazebrook, a dedication to Lord Kelvin, a preface by the author and an introduction by the late Silvanus P. Thompson. One striking and characteristic remark in this introduction by Thompson—a really devoted and profound scholar in the same line with Dr. Mottelay—deserves quotation. "The art of scientific discovery—for it is an art—can be obtained but in one way, the way of attainment in all arts, namely, by practicing it." At the other end of the volume the reader is fortified by an index of no mean proportions, covering 109 octavo pages, something unusual in an English book. Here one finds much new information and many cross-references, adding distinct value to a work which is already indexed in a chronological sense.

Concerning the main body of the work, it is interesting to find only seven references which antedate Thales, the point at which most electrical histories begin; and in none of these seven citations is the reader convinced that any electrical or magnetic phenomenon is referred to save only in the case of Job (xxxviii, 35) where one is sure that "lightnings" never connoted to this patient poet anything electrical. To Job, lightning was merely a phenomenon of the atmosphere.

In the case of magnetic phenomena, some of these early descriptions are surprisingly accurate. Witness the following account of magnetic induction from St. Augustine's "City of God" (426 A. D.):

> When I first saw it (the attraction of the magnet), I was thunderstruck (*vehementer inhorrui*), for I saw an iron ring attracted and suspended by the stone; and then, as if it had communicated its own property to the iron it attracted and had made it a substance like itself, this ring was put near another and lifted it up, and, as the first ring clung to the magnet, so did the second ring to the first. A third and fourth were similarly added, so that there hung from the stone a kind of chain of rings with their hoops connected, not interlinking but attached together by their outer surface. Who would not be amazed by this virtue of the stone, subsisting as it does, not only in itself, but transmitted through so many suspended rings and binding them together by invisible links?

There can be no two opinions about the great service which Dr. Mottelay has rendered in placing at our disposal this enormous collection of electrical notes arranged in an orderly way, enabling one to obtain with the least possible trouble some desired bit of information. At the same time, one does not read very far into this chronology without discovering that many of the opinions quoted are of little value, and that the critical judgment of the compiler is practically never given.

It is all very well to quote opinions which represent the various sides of a question and allow the reader to form his own judgment; but when it comes to introducing Paracelsus, Mesmer and Mme. Blavatsky as electrical witnesses (which is done in more than a dozen different paragraphs) the author is perhaps beyond the line which separates the useful from the useless.

On the other hand, these "mere opinions" are sometimes instructive as illustrating the difficulty of appraising one's contemporaries. Thus, Lord Bacon, in 1604, says of Gilbert's great treatise on magnetism which was published some four years earlier:

> Gilbert has attempted to raise a general system upon the magnet, endeavoring to build a ship out of materials not sufficient to make the rowing-pins of a boat.

This concerning the man whom Poggendorff, two centuries away from the canvas, calls "the Galileo of Magnetism" and who was named by Priestley as "the Father of Modern Electricity." Dr. Mottelay devotes ten pages to Gilbert; but nowhere does he set forth the essential contributions which this great pioneer made to electro-statics and magnetism. No indication is given, for example, of the essential distinction between Gilbert's "electrics" and "non-electrics"—a classification which is still valid and useful.

For one who is seeking odd facts and curious bits of information, this chronology is an inexhaustible mine. Such, for example, as the following: that Otto von Guericke (1660) was the first to hear and see the light in artificially produced electricity; that Halley's magnetic voyage in a British vessel (1698) was the first scientific expedition by any government; that the use of the magnet for removing a foreign particle of iron from the human eye dates from the year 1700; that the word *magnetism* is first used by William Barlow in 1613; that spider webs were first used for suspensions by Fontana at the University of Padua

in 1775; cobalt was shown to be magnetic as early as 1733, and nickel in 1750.

Concerning these and the many other strange facts scattered through the pages of this book, the surprising thing is to find how early in the game most of the known phenomena of electrostatics were discovered. One finds here dozens of illustrations of the well-known fact that nearly every great discovery in physics has been not only adumbrated but more or less clearly anticipated. Thus the law of inverse squares was distinctly enunciated by Lambert twenty years before the experiments of Coulomb. Nor is it less amazing to see what an enormous amount of fiction has been seriously reported as fact. A paper read before the Royal Society in 1749 explains earthquakes as caused by electricity; an eminent Frenchman, Boulanger, writes a treatise on electricity in 1750, in which he explains that black ribbons are more readily attracted than those of other colors, etc.

This collection of Dr. Mottelay is a veritable treatise on the embryology of electrical science, which will be wanted in every public library, and will be indispensable to students of the history of physics. So long as there is no *index expurgatorius* for electrical books there will ever remain the need for competent critics who can hand on the really essential features of each period, who can appraise the relative merits of various investigations, and who possess the perspective necessary to set forth, in their proper succession and relation to each other, the great discoveries of science. Such a developmental history means much economy of thought. A critical history of this type which would do for the entire subject of electricity and magnetism what Whittaker has done for a portion of the subject in Chapters II and III of his "History of the Theories of Aether and Electricity" would form a worthy companion-volume to that of Dr. Mottelay.

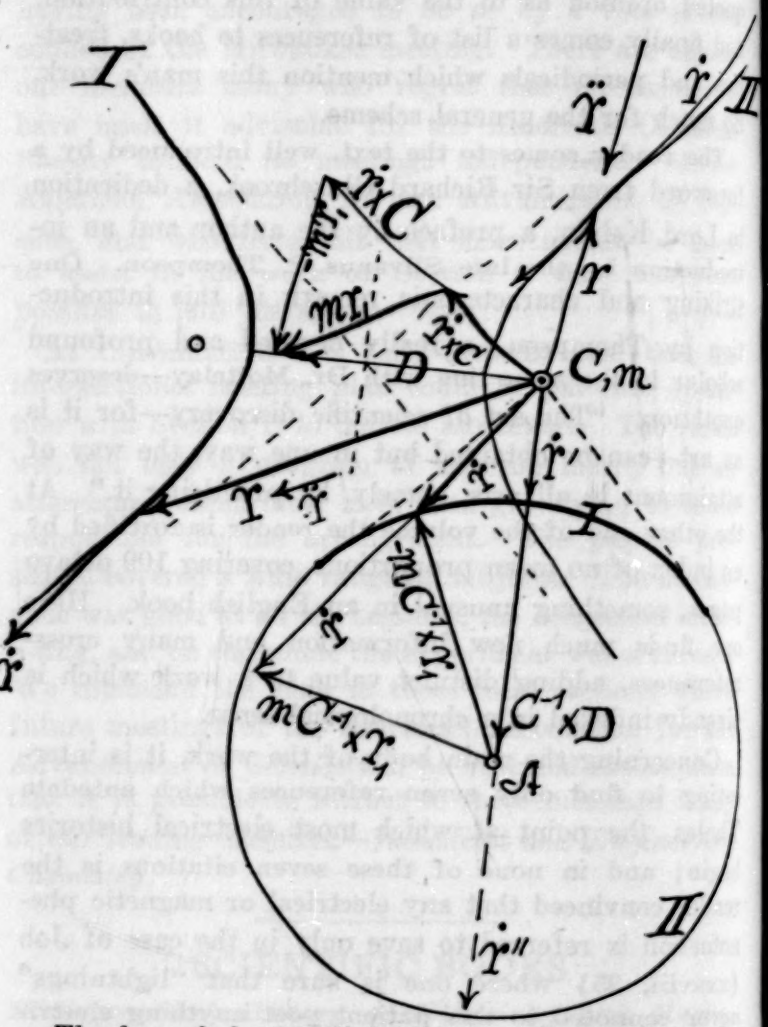
HENRY CREW

SPECIAL ARTICLES

THE HODOGRAPH OF NEWTONIAN HYPERBOLIC REFLECTION

APROPOS of Sir Oliver Lodge's recent treatment (*Nature,* January 5, 1924) of the reflection of atomic nuclei, a graphic exhibit of the hodograph of such cases which we have been considering in my classes may be given, as it contains many interesting features. The vector equations[1] taken in succession (if r is the radius vector, C the angular momentum per gram of planet, m the mass of the repulsive sun and D a vector along the major axis) are: $d^2r/dt^2 = r_1 m/r^2$, $C = r \times dr/dt$, $D = (dr/dt) \times C + mr_1$, $dr/dt = C^{-1} \times (D - mr_1)$, the subscript denoting a unit vector. For the case of hyperbolic motion subject to an attracting sun it is then merely necessary to change m into $-m$.

The figure gives the twin hyperbolas with their common axis and asymptotes. If a repelling mass is at m, and C is a normal vector erected there outward (the usual electrical symbol) the hyperbola I on the left is in question. The diagram gives all the vectors (heavy lines) for the construction of the hodograph with its center at A. It is interesting to see that only the part I of the hodograph is needed. This is limited by tangents parallel to the asymptotes and comprehending the smaller velocities (minimum primed in figure, being normal to D).



The hyperbola *II* (light lines) and the remainder of the hodograph belong together and these correspond to an attracting mass at m. Consequently the velocities are all relatively large with a maximum $(dr/dt)''$, again normal to D. All vectors through m originate there. The aim is along the asymptotes.

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STIMULATION OF THE VAGUS NERVE

FOLLOWING a suggestion made to me by Professor W. B. Cannon, I have found that a definite relationship exists between frequency and strength of stimulation of the vagus nerve in the cat and the effects

[1] Vectors in roman.

produced on the lower end of the esophagus, the cardia and the fundus et corpus ventriculi. Relatively low frequencies and intensities of stimulation cause pronounced contraction. Increase in frequency or strength beyond that of the excitatory stimulation, on the contrary, after producing first an initial contraction, leads to relaxation during stimulation and strong after-contraction on cessation of stimulation. Repetition of the inhibitory stimulation during the after-contraction causes relaxation, and is followed again by contraction. These effects are produced most readily in the lower end of the esophagus. When this part of the gullet has been thrown into contraction by excitatory stimulation of the vagus, an increase either in frequency or strength of stimulation evokes relaxation. Conversely, relaxation gives place to contraction, when in a period of inhibitory stimulation either frequency or intensity is diminished.

The fundamental difference in effect produced by the two types of stimulation is illustrated further by simultaneous stimulation of both vagi. In the case of the lower end of the esophagus, excitatory stimulation of one vagus may have little or no effect if repeated during the relaxation caused by simultaneous inhibitory stimulation of the other vagus. Moreover, the strong contraction produced by excitatory stimulation of one vagus may be reduced practically to nothing by simultaneous inhibitory stimulation of the opposite vagus.

The above reactions are independent of the cardio-inhibitory action of the vagus.

The change from contraction to relaxation on increase in frequency or strength of vagal stimulation is analogous to the Wedensky effect,[1] and it may be explained on similar grounds. It may have important bearing on processes of inhibition in general. The reaction which occurs when stimulation of relatively high intensity or frequency is applied to the vagus stands in close relationship to such phenomena as reversal of the action of the vagus on the heart,[2] and reflex rebound.[3] It is quite typical also of reactions characterized by initial increase of activity of the effector on stimulation of its nerve, followed by decrease of activity during stimulation, and a second increase on cessation of stimulation. Such reactions are seen under certain conditions in the action of the chorda tympani on the submaxillary gland,[4] the nervus erigens on the bladder,[4] and the cervical sympathetic on the m. dilatator pupillae.[5] It is probable that the change from an excitatory to an inhibitory effect on increase in frequency or strength of stimulation of the vagus will throw light on these imperfectly understood phenomena.

A full account of this investigation will be published in the *American Journal of Physiology*.

H. O. VEACH
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[1] Wedensky, N., *Archiv. f. d. ges. Physiol.*, 1885, XXXVII, p. 69; *Archives de Physiol.*, 1891, XXIII, p. 687.

[2] Dale, Laidlaw and Symons, *Journ. Physiol.*, 1910, XLI, p. 1.

[3] Sherrington, C. S., *Proc. Roy. Soc.*, 1908, B, LXXX, p. 53.

[4] Langley, J. N., *Journ. Physiol.*, 1911, XLIII, p. 125.

[5] Dale, Laidlaw and Symons, *Journ. Physiol.*, 1910, XLI, p. 16.

THE INDIANA ACADEMY OF SCIENCE

THE Indiana Academy of Science held its thirty-ninth annual meeting at DePauw University, Greencastle, Indiana, on December 6 to 8. The following program was presented:

GENERAL SESSION

Brief Business Session.

Presentation of Papers of General Interest.

Causes of and remedies for the inefficiency of locomotive whistles: ARTHUR L. FOLEY.

The southern Ute Indians of Pine River Valley, Colorado: ALBERT B. REAGAN.

Variations among Indiana counties in the death rate: S. S. VISHER.

A plea against over-standardization in scientific education: E. G. MAHIN.

Presidential Address: *Bacteriology and its practical significance:* CHARLES A. BEHRENS.

SECTIONAL MEETINGS

BOTANY–ZOOLOGY

Does Allium vineale L. produce seeds in Indiana? Recent Indiana weeds; A weed survey of Indiana: A. A. HANSEN.

Indiana fungi: J. M. VAN HOOK.

Plants new or rare to Indiana—XII: CHAS. C. DEAM.

Culture methods in the production of polyembryony in certain ferns (Polypodiaceae); Behavior of fern prothallia under prolonged cultivation: D. M. MOTTIER.

Plant relations in Brazos County, Texas: ELMER GRANT CAMPBELL.

The trees of Vanderburg County: A. J. BIGNEY.

Some soil and water reactions in the dunes region of Porter County: M. W. LYON, JR.

Notes on grasses: PAUL WEATHERWAX.

Indiana plant diseases, 1923: MAX W. GARDNER.

Nitrate studies on Purdue rotation field number 6: I. L. BALDWIN, W. J. NICHTER, R. O. LINDSEY.

Cultural methods with rusts: E. B. MAINS.

Plants of White County—VI: LOUIS F. HEIMLICH.

Notes on the life history of the snapdragon rust, Puccinia antirrhini: E. B. MAINS.

An ecological view of wet waste land: BLANCHE MCAVOY.

Preliminary notes on comparative growth in grazed and ungrazed woodlots at Purdue: BURR N. PRENTICE.